A HESS'S LAW INVESTIGATION

INSTRUCTOR RESOURCES

The CCLI Initiative

Learning Objectives

- measure the heats of reaction for two chemical reactions.
- use Hess's Law, in conjunction with the above measurements, to calculate the heat of reaction for the combustion of magnesium metal.

Procedure Overview

- time/temperature program used with a Styrofoam cup calorimeter.
- ΔT values are determined graphically for Mg/HCl and MgO/HCl reactions.
- Hess's Law is used to determine the heat of combustion of Mg.

Name ______________________________ Section __________ Date ____________________

HESS' LAW INVESTIGATION

Report Sheet

Magnesium/HCl Reaction

Grams of Magnesium	_______________	g
Final Temperature	_______________	ºC
Initial Temperature	_______________	ºC
ΔT	_______________	ºC

Magnesium Oxide/HCl Reaction

Grams of MgO	_______________	g
Final Temperature	_______________	ºC
Initial Temperature	_______________	ºC
ΔT	_______________	ºC

Name ______________________________ Section __________ Date ____________________

HESS' LAW INVESTIGATION

Report Sheet (page 2)

Calculations

1. Calculate ΔH for the Mg/HCl reaction in kJ/mole of Mg. Show your work.

2. Calculate ΔH for the MgO/HCl reaction in kJ/mole of MgO. Show your work.

3. Write the three thermochemical equations needed to calculate ΔH for the reaction below. Include ΔH values for each reaction.
   $2\ Mg\ (s) + O_2\ (g) \rightarrow 2\ MgO\ (s)\quad \Delta H = ?$

4. *Neatly* rewrite the three equations (multiply, reverse directions, etc.) such that when added, the result is the thermochemical equation above for the combustion of magnesium. Calculate ΔH for this reaction. Show your work.

Name ______________________________ Section __________ Date ____________________

HESS' LAW INVESTIGATION

Questions/Problems

1. Using the thermochemical tables in your textbook, determine the theoretical ΔH for the following reaction:

$$2\ Mg\ (s) + O_2\ (g) \rightarrow 2\ MgO\ (s)$$

2. Explain why the calculated value from your experiment differs from the theoretical value for the heat of reaction above.

3. Why are adiabatic conditions necessary for this experiment?

Hess' LAW INVESTIGATION

Suggested Answers to Questions/Problems

1. Using the thermochemical tables in your textbook, determine the theoretical ΔH for the following reaction:

   $2\ Mg\ (s)\ +\ O_2\ (g)\ \rightarrow\ 2\ MgO\ (s)$

   From standard enthalpies of formation

   ΔH_f^o for MgO(s) is −601 kJ/mol

   $\Delta H\ =\ 2(-601)\ =\ -1202$ kJ

2. Explain why the calculated value from your experiment differs from the theoretical value for the heat of reaction above.

   a. ***Limitation in accuracy of temperature measurement*** **(±0.1ºC*****) as a function of the calibration.***

   b. Standard state conditions not used.

   c. Error in value for specific heat of solution.

   d. Non-adiabatic conditions.

3. Why are adiabatic conditions necessary for this experiment?

   The calculations assume that all heat released in each chemical reaction goes into warming the resulting solution and cup.

Hess' LAW INVESTIGATION

Tips and Traps

1. Stirring is critical in this lab.
   a. Stirring should be vigorous without splashing.
   b. Magnetic stirrers may cause interference with the computers. If so, manual stirring will be necessary.

2. Make sure that the Mg and the MgO are added to the solution in such a manner that they do not stick to the sides of the container.

3. The temperature probe must be *in* the solution without touching the bottom of the container or the magnetic stir bar.

4. The temperature probe must be supported in some manner to hold it in a vertical position. This can be done by draping the cord across a utility clamp or by simply holding the thermistor in an upright position.

5. Magnesium oxide can be a messy chemical to weigh. It is a fine white powder. Keep a vigilant watch on the balance area.

6. Use magnesium turnings or ribbon. Do not use Mg powder. Its reaction is too violent.

7. An alternative method for supporting the foam cups is a suitable iron ring (3-inch).

8. You need a cover for the foam cups. There are many alternatives; two are suggested below:
   a. A plastic coffee cup lid
   b. A foam square, 3.5" x 3.5" x 0.5" with a hole in the middle for the thermistor. A rubber band or small piece of rubber hose around the thermistor will prevent it from slipping through the foam block or the coffee cup cover.

HESS'S LAW INVESTIGATION

Sample Data

The following sample data consists of (1) the masses of Mg and MgO, (2) the temperature changes involved in the experiments, (3) the graphs of the time-temperature data for the Mg and MgO reactions, and (4) the calculations.

Magnesium/HCl Reaction

Grams of Magnesium	0.244	g
Final Temperature	32.2	ºC
Initial Temperature	21.3	ºC
ΔT	10.9	oC

Magnesium Oxide/HCl Reaction

Grams of MgO	0.996	g
Final Temperature	28.8	ºC
Initial Temperature	21.4	ºC
ΔT	7.4	ºC

Hess' LAW INVESTIGATION

Sample Data (page 2)

Calculations

1. Calculate ΔH for the Mg/HCl reaction in kJ/mole of Mg. Show your work.

   heat = (3.86) x (100) x (10.9) + (30) (10.9) = 4.53 kJ

   ΔH = (−4.53/0.244) x (24.3) = −452 kJ

2. Calculate ΔH for the MgO/HCl reaction in kJ/mole of MgO. Show your work.

   heat = (3.86) x (101) x (7.4) + (30) (7.4) = 3.11 kJ

   ΔH = (−3.11/0.996) x (40.3) = −126 kJ

3. Write the three thermochemical equations needed to calculate ΔH for the reaction below. Include ΔH values for each reaction.

   $2\ Mg\ (s) + O_2\ (g) \rightarrow 2\ MgO\ (s)$ ΔH = ?

   $Mg\ (s) + 2\ HCl\ (aq) \rightarrow MgCl_2\ (aq) + H_2\ (g)$ ΔH = −452 kJ

   $MgO\ (s) + 2\ HCl\ (aq) \rightarrow MgCl_2\ (aq) + H_2O$ ΔH = −126 kJ

   $2\ H_2\ (g) + O_2\ (g) \rightarrow 2\ H_2O\ (l)$ ΔH = −572 kJ

4. *Neatly* rewrite the three equations (multiply, reverse directions, etc.) such that when added, the result is the thermochemical equation above for the combustion of magnesium. Calculate ΔH for this reaction. Show your work.

   $2\ Mg\ (s) + 4\ HCl\ (aq) \rightarrow 2\ MgCl_2\ (aq) + 2\ H_2\ (g)$ ΔH = 2 (−452) kJ
   $2\ MgCl_2\ (aq) + 2\ H_2O\ (l) \rightarrow 2\ MgO\ (s) + 4\ HCl\ (aq)$ ΔH = 2 (+126) kJ
   $2\ H_2\ (g) + O_2\ (g) \rightarrow 2\ H_2O\ (l)$ ΔH = (−572) kJ

   $2\ Mg\ (s) + O_2\ (g) \rightarrow 2\ MgO\ (s)$
   ΔH = 2 (−452) + 2 (+126) + (−572) = −1224 kJ

Hess'S LAW INVESTIGATION

Suggested Answers to Questions/Problems

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   $2\ Mg\ (s) + O_2\ (g) \rightarrow 2\ MgO\ (s)$

   From standard enthalpies of formation

   ΔH_f^o for MgO(s) is −601 kJ/mol

   $\Delta H = 2(-601) = -1202$ kJ

2. Explain why the calculated value from your experiment differs from the theoretical value for the heat of reaction above.

   a. ***Limitation in accuracy of temperature measurement* (±0.1ºC) *as a function of the calibration.***

   b. Standard state conditions not used.

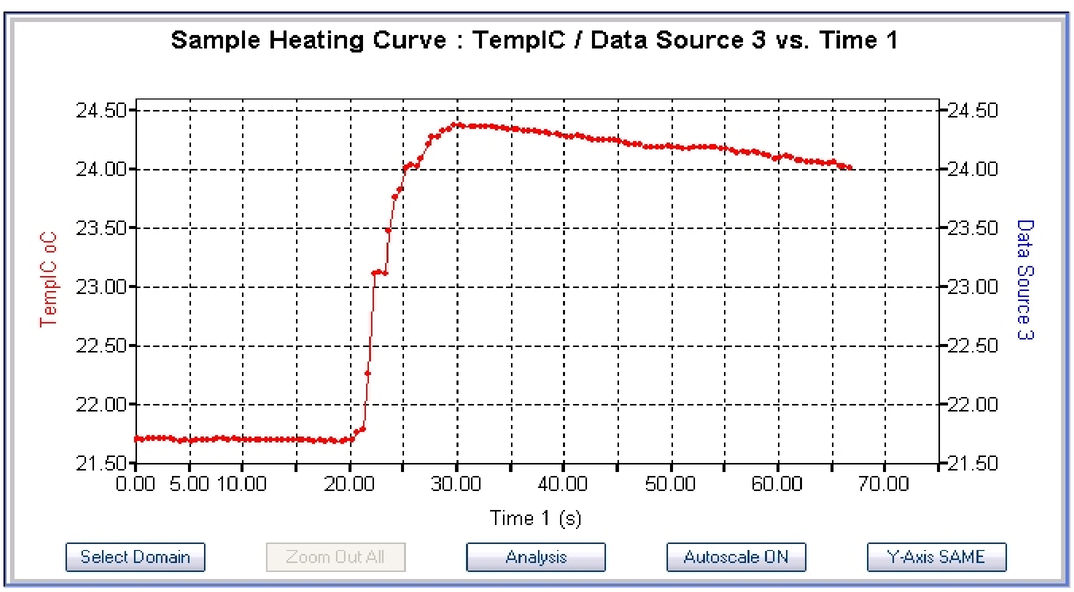
   c. Error in value for specific heat of solution.

   d. Non-adiabatic conditions.

3. Why are adiabatic conditions necessary for this experiment?

   The calculations assume that all heat released in each chemical reaction goes into warming the resulting solution and cup.

A sample ***MicroLAB*** heating curve.



Hess'S LAW INVESTIGATION

Laboratory Preparation (per student station)

Equipment

- thermistor
- ring stand
- utility clamp
- two foam cups (nested into a 250 ml beaker to form a calorimeter)
- magnetic stirrer and stir bar
- cover for foam cup
- 100 ml-graduated cylinder

Supplies

- weighing paper or weighing boat

Chemicals

Actual quantities needed are given below. A 50% excess is recommended.

- 0.25 g Mg turnings or ribbon
- 1.0 g MgO
- 200 ml 1 *M* HCl

Safety and Disposal

1 *M* HCl is corrosive and dangerous to the eyes. Make sure your students are wearing goggles at all times.

all resulting solutions may be flushed down the drain with plenty of water.